Occasional Papers On Mollusks

Published by
THE DEPARTMENT OF MOLLUSKS
Museum of Comparative Zoölogy, Harvard University
Cambridge, Massachusetts

VOLUME 3 JUNE 29, 1973 NUMBER 46

DISTRIBUTION OF HYDROBIIDAE, A FAMILY OF FRESH AND BRACKISH WATER GASTROPODS, IN PENINSULAR FLORIDA

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Abstract: The distribution of the species of Hydrobiidae, a family of fresh and brackish water gastropods, of peninsular Florida was re-examined. An alternate interpretation of the distributional data to that presented by Thompson (1968, The aquatic snails of the family Hydrobiidae of peninsular Florida. Univ. Fla. Press, Gainesville) is suggested. The peninsula is considered to be the region below the Suwannee River system in the west and the St. Marys River system in the east, since it is the area below these systems that was reduced to a number of islands during Wicomico flooding in the Late Pliocene or Early Pleistocene, when the sea was 90 to 100 feet above the present level. With the exception of two species that may have had refugia on the islands, and one that may have speciated, it is argued that the re-emerged peninsula was invaded by species from the Southern Atlantic Slope and Apalachicolan regions. The peninsula remained connected throughout the Pleistocene but was inundated to a height of 25 to 30 feet during the Yarmouth interglacial when the Pamlico terrace was formed. The inability of some of the species in the older part of the peninsula to occupy it fully,

as well as the absence of many of them beyond the Pamlico terrace appear to add credence to evidence that the Pleistocene was of much shorter duration than formerly thought. A number of species, restricted to the Atlantic side of Pamlico terrace, which have not penetrated far south suggest that they are of recent continental origin, while others are obviously from the West Indies. It is suggested that from this fauna there appear to have evolved rapidly some 14 endemic species, mostly confined to individual springs, many near the edge of the Pamlico terrace.

Acknowledgments

Special thanks are extended to Dr. Kenneth J. Boss for his encouragement and interest in this paper. He kindly read the manuscript and made suggestions as did Drs. Ernest Mayr and Michael A. Rex. Dr. Ruth D. Turner also unselfishly aided me. The cost of the photographs was generously borne by the William F. Milton Fund, Harvard University.

Introduction

Peninsular Florida is an especially interesting area for the study of the speciation and distribution of certain groups of animals because the present peninsula, which is a component of a much larger unit, the Florida Plateau, has been subjected to numerous inundations by the sea. The Plateau is nearly level, the highest part (near Haines City, Polk County) being only 350 feet above the present sea level. Nearly two-thirds of the present peninsula is only 50 feet above sea level.

The highest recognized marine shore line in peninsular Florida is at an altitude of from 215-270 feet (depending on the authority) above the present one. At the time that shore line was formed all of Florida was inundated except for several small islands in the vicinity of Polk County. Cooke (1945: 273, fig. 43) thought that this flooding, which formed the Brandywine terrace (Citronelle formation in

the southeast), took place in the early Pleistocene during the Aftonian interglacial stage, but Alt and Brooks (1965: 408) concluded that flooding occurred during the Upper Miocene (Table 1.) Laessle (1968) later confirmed this dating with botanical evidence. It is not possible to tell if any of the present fresh water mollusks in the peninsula have persisted since this time.

The highest Pleistocene shore line recognized by MacNeil (1950, pl. 1), the Okefenokee or Sunderland of Cooke (1945: 278, fig. 43) though not specifically recognized by Alt and Brooks (1965) or Alt (1968), was formed during the Pliocene when the sea was 150 feet higher than it is now. (See: Pl. 49, Fig. 1). All that remained of the peninsula was part of Trail Ridge, which formed a large, pear-shaped promontory in Bradford and Clay Counties; there were three irregular roughly parallel ridges in Polk and Highlands Counties in Central Florida; high hills between Dade City and Brooksville, in Pasco and Hernando Counties became islands; to the north numerous small hills stood above the 150 foot level; and a large expanse of rocks of the Hawthorne Formation formed an island farther north in Alachua County.

The Wicomico Shore line (Cooke, 1945: 281, fig. 44) is the least sharply defined of the shores recognized by MacNeil, which might indicate that the sea stood at this level for a comparatively short time. (See Pl. 49, Fig. 2)

It was formed during the Pliocene (Alt, 1968: 92) when the sea level was 90 to 100 feet higher than at present. Florida was again reduced to a number of islands in Pasco, Hernando, Citrus, Sumter and Marion Counties. Hubbell (1954: 48, 49; 1956: 86) studying the flightless dung beetle genus, *Mycotrupes*, concluded, on zoogeographical evidence, that the five species that now live on "islands" of sandy plains or hills separated by marshes or other nonsandy habitats, evolved on actual islands in the interglacial seas and that some land areas persisted in Florida throughout the Pleistocene. Swift (1970: 325) said of a total primary freshwater fish fauna of 47 species that now inhabit either

the St. Johns or Suwannee Rivers or both, "Only three species of primary freshwater fishes apparently arose in south or central Florida" and supported the view of moderate Pleistocene flooding. Gilbert and Bailey (1972: 27) speak of the last unquestioned complete separation of peninsular Florida as occurring during the late Pliocene in their paper on the Cyprinid fish *Notropsis emiliae*. They suggest that the subspecies *N. e. peninsularis* evolved, as did the endemic peninsular [sub]species of largemouth bass, *Micropterus salmoides floridanus* (Bailey and Hubbs, 1949: 31, map 1), when Florida was an island. They mention that the former came into contact with the nominate subspecies in neighboring river systems to the north, the Suwannee and Ochlockonee to the north west and the St. Marys and Satilla to the north east.

The hydrobiid, *Amnicola dalli johnsoni* Pilsbry may be a similar instance of contact with the nominate subspecies, *A. dalli dalli* (Pilsbry and Beecher) though the evidence is not conclusive.

In the area of Wicomico flooding below the Suwannee River system in the west and the St. Marys River system in the east, Johnson (1972: 181) found 12 species of Unionidae, or fresh water mussels, belonging to 6 genera. Nine of the species appear to have spread into the peninsula after Wicomico flooding from the Apalachicolan region to the west and north where there are 49 species in 17 genera. Johnson (1970: 269) defined the Apalachicolan region as consisting of those rivers which flow into the Gulf of Mexico from the Escambia to the Suwannee, including the St. Marys and Satilla which enter the Atlantic directly, since their modest unionid faunas consist entirely of species found in the Apalachicolan region.

One species, *Elliptio buckleyi* (Lea), may have persisted on the peninsula at least since the Pliocene,[1] while another,

[1] *Unio caloosaensis* Dall (1895, Trans. Wagner Free Inst. Sci. 3 (3): 688, pl. 25, figs. 5, 12b found in the Pliocene marls of the Caloosahatchie River) is either *E. buckleyi* (Lea) or is closely related to it.

Villosa amygala (Lea) may have derived from *V. lienosa* (Conrad) on one of the larger land masses.

Thompson (1968: 15) on the basis of the distribution of 35 species of Floridian Hydrobiidae (the area from the St. Marks River system in the west to the St. Marys in the east as well as the peninsula is included) suggested that a peninsula persisted throughout the Pleistocene and refuted the marine origin of any terrace other than the Pamlico. My interpretation of his data, (with the exception of *Hyalopyrgus brevissimus* (Pilsbry), *H. aequicostatus* (Pilsbry), and possibly *Amnicola dalli johnsoni* Pilsbry, that may have survived in *refugia,* or else speciated on islands in the Wicomico sea) is that many of the species migrated into the peninsula after Wicomico flooding. A number of the species have not yet fully occupied the older part of the peninsula, nor penetrated beyond the Pamlico terrace. This distrbution suggests a rather recent repopulation of the older peninsula from the west and north, and casts doubt on the classical Quaternary time table. The Pleistocene is generally held to have consisted of four major glaciations each lasting approximately 100,000 years, separated by interglacials ranging in length from 100,000 to 300,000 years. Emiliani (1972), on the basis of oxygen isotopic analysis of Caribbean cores, suggested that the temperature cycles of the Quaternary were of much shorter duration than previously held. The limited penetration of certain Unionidae and Hydrobiidae in the peninsula appear to support his data.

The Pamlico Shore line, the best preserved of the Pleistocene shores, was formed during the Yarmouth interglacial stage when the sea was 25-30 feet above the present level (See: Pl. 49, Fig. 3). At this time, the shape of Florida was much as it is today, except that the peninsula was narrower and shorter, terminating near Lake Okeechobee. Off the southwestern end of the peninsula was a large oval island. A long, wide lagoon, including the present St. Johns River, extended southward from Orange Bluff on the St. Marys River to Sanford, and was separated from the open ocean by a chain of islands.

The shore extended much farther out on the Plateau as little as 11,000 years ago (See: Pl. 49, Fig. 4). At that time, it may have been easier for Hydrobiidae and Unionidae to disperse along a largely baseleveled coast (Adams, 1901), which may explain the presence of one unionid, *Elliptio dariensis* (Lea), in only the Altamaha and St. Johns river systems. The distribution of some species of Hydrobiidae, presently restricted to the ocean side of the Pamlico shore appears to offer striking evidence of recent repopulation. The presence of 14 endemic species, mostly confined to individual springs, many near the edge of the Pamlico shore, suggest rapid speciation.

Re-interpretation of the Distribution of the Hydrobiidae of Peninsular Florida

In a recent study of the family Hydrobiidae of peninsular Florida, Thompson (1968: v) stated that the geographical and ecological distributions of most of the species of these fresh and brackish water snails suggest that, "the peninsula of Florida was maintained as an emerged peninsula since the Pliocene, and was not reduced to an island or archipelago as some biogeographers and geologists have proposed." This conclusion was based on his interpretation of the distribution of 35 species of hydrobiids representing 10 genera found on the Florida peninsula, which in his study, as previously stated, included the Suwannee and St. Marys river systems. These geographical limits were chosen, "because the molluscan fauna of the peninsula is different from that of the north and west and the important transition occurs in the region of the neck of the peninsula."

Although data on the species found in the Apalachicolan region west of the Suwannee River system or those of the Southern Atlantic Slope are scanty, information on the wider distribution of some of the genera is included in Thompson's study, which does not appear to support the

statement: "Ecological and geographical considerations argue against the possibility that these snails invaded the peninsula from the north since the proposed inundation." Thompson (1968: fig. 1) collected at a very comprehensive number of field stations. From these extensive data he produced a number of distributional maps, which when re-examined, support my interpretation that many of the hydrobiids have repopulated the peninsula since the Pliocene inundation of 90 to 100 feet and some of them since the formation of the Pamlico shore during the Yarmouth interglacial stage.

Thompson recognized 14 endemic species in 4 genera, confined for the most part to individual springs, (many of which are on the outer side of the Pamlico shore line). Unless these are ecophenotypic variants, they represent rapid speciation (Pl. 52, Pl. 53, Figs. 1, 2).

Other species, also confined to the ocean side of the Pamlico shore, (Pl. 52, Pl. 53, Figs. 1-2) must have arrived there from elsewhere when the land extended much farther out onto the continental shelf, or else they have speciated there rapidly. The lack of penetration of the central portion of the peninsula by many species that appear to have come from the west and north suggests that they arrived later than Thompson thought or that niches for their survival in this region are lacking.

Thompson (1968: 14) correctly rejected the importance of the Aftonian flooding of Cooke, when the sea level was thought to have been some 250 feet higher, since this flooding is now considered to have occurred during the Upper Miocene (Alt and Brooks, 1965: 408) and probably has no relationship to the present fresh-water molluscan fauna. He also rejected the flooding to the 90-100 feet shore line. This, the Wicomico shore, (Plate 49, Fig. 2) was formerly thought to have been formed during the Sangamon interglacial stage, but is now regarded as Pliocene age (Table 1). Of Wicomico flooding Thompson (1968: 14) said:

> A rise in sea level of 100 feet would be sufficient to separate central Florida from the mainland and to create a waterway through the Suwannee Straits and would have been sufficient to inundate all of the (present) important springs, streams, and lakes of the Florida peninsula. The only water sysem that could have remained would have been small, landlocked lakes in sandy soil.

He cited five arguments why the geological evidence of Aftonian flooding should be dismissed, based on his analysis of the distribution of the Hydrobiidae. It has already been suggested that this Miocene flooding (Pl. 49, Fig. 1) has no bearing on the present fresh water molluscan fauna. Since Thompson also rejected Wicomico flooding his arguments are refuted with his denial of it in mind.

1. "The only species of hydrobiids found in Polk County at the present time is *Amnicola johnsoni*. If other species had resided here during the Aftonian interglacial there should be relict populations." Pl. 49, Fig. 2 shows that there were larger land masses than just Polk county in the Wicomico Sea. If Thompson's concept of *A. dalli johnsoni* is correct, it would appear that it became an endemic during its isolation on a land mass in the Pliocene and has come into contact with the nominate subspecies, as have some fishes (discussed on p. 284) in the Suwannee River system.

Thompson (1968: 45) suggested that the genus *Hyalopyrgus* originated in Florida. The present distribution of *H. brevissimus* and *H. aequicostatus* (Pl. 53, Figs. 3, 4) indicate that they may have persisted on islands in the Wicomico Sea (Pl. 49, Fig. 2).

2. "If the vagility of the snails was such that they could have immigrated into the peninsula since the Kansas glaciation, they should have been able to invade the more southern areas of the peninsula as it became exposed." The implication of the distributional maps of a number of the species (Pls. 50, 51) is that they are of western or northern origin and, like *Elliptio dariensis* (Lea) (Johnson, 1972: 186), have entered Florida so recently that they have not had

time to spread more widely, or that niches for their survival are lacking. "They should also have been able to move into other areas of the southeastern states." While there is no modern study of the hydrobiid mollusks of the southeastern states to corroborate this statement, it would be surprising if none of the Floridian species were found there. "Such a high degree of vagility would also preclude the genetic isolation and speciation that has occurred in *Cincinnatia* and *Aphaostracon*." The genus *Cincinnatia* is widespread in the United States, *C. floridana* is found in the Suwannee River system and central Florida and *C. fraterna* (Pl. 51, Fig. 4) is found only on the ocean side of the Pamlico Terrace and must either be found on the Atlantic Slope or have speciated quickly. The remaining 8 species in these genera are endemic, usually limited to a single spring often either near the edge of the Pamlico Terrace, or on the ocean side of it. *Aphaostracon* has one species, *A. hypohyalina* (Pl. 51, Fig. 1) which is even more restricted than *C. floridana* (Pl. 50, Fig. 2), being limited to the Suwannee River system. *A. rhadinus* (Pl. 51, Fig. 1) has a distribution similar to *C. fraterna* (Pl. 51, Fig. 4) on the northern ocean side of the Pamlico, and *A. pachynotus* (Pl. 53, Fig. 2) is essentially restricted to the lower Pamlico. All of these species appear to be recent arrivals. Four of the 6 endemic species occur close to the edge of the Pamlico Terrace.

3. "If the recent hydrobiids had immigrated from the north, they would have had to do so across a strait that extended through the present headwaters of the Suwannee River system and the St. Marys River system and to the highlands of Georgia to the north of the headwaters. This area of Georgia is nearly devoid of mollusks, especially hydrobiids, due to the acidic soils which result from the laterites and igneous bedrock that underlie this region. There is no reason to believe that the area would have been more hospitable to snails in the past." The geological evidence of an inundation of the sea during the Pliocene to a height of 90-100 feet above the present level, which

reduced peninsular Florida to a number of islands, is well established. The fact that the distribution of a number of hydrobiids is restricted to the northern and northeastern part of the peninsula might indicate that these species or their ancestors invaded the peninsula rather recently and have not yet widely spread. There is no evidence that the St. Marys and Satilla river systems have been barriers to the spread of some molluscan species. *Elliptio dariensis* (Lea) is found in both the Altamaha, an old river system, and the St. Johns, a system of recent origin as is *Littoridinops tenuipes* (Cooper) (Pl. 52, Fig. 2). As recently as 11,000 years ago the sea level was much lower than at present (Emery, 1967: 66) and it was probably easier for molluscan species to spread along the largely baseleveled continental shelf than it is today. This opportunity must have occurred several times during glacial periods.

4. "If *Cincinnatia, Hyalopyrgus, Aphaostracon, Spilochlamys,* and *Notogillia,* or ancestral forms, had migrated into the peninsula after the Aftonian Sea, it is not likely that they could have differentiated to the degree that they have in so short a time." It now appears that Florida has been an emerged peninsula since the early Pleistocene, but the inundation of the late Pliocene was considerable. Peradventure the repopulation of the peninsula has been slow and is continuing.

Enough endemic species of *Cincinnatia* and *Aphaostracon* are found on the ocean side of the Pamlico Terrace to make the assumption of rapid speciation from congeners necessary. The two species of *Hyalopyrgus* (Pl. 53, Figs. 3, 4) indicate that they might be relicts. *Spilochlamys conica* (Pl. 50, Fig. 4) is almost confined to the Apalachicolan region, while *S. gravis* (Pl. 50, Fig. 4) may be of Atlantic Slope origin. *Notogillia wetherbyi* (Pl. 50, Fig. 3) appears to be a re-introduction from the Apalachicolan region.

5. "If these forms evolved on the mainland, and migrated on to the peninsula, why should they not occur in their former ranges?" It has not been proven that they do not occur in their former ranges. It has been suggested here, on the geological and faunal evidence, that the Suwannee River system was probably a *refugium* for some species, and is, indeed, part of the former range of those species shown on Plate 50. Plates 51; 52; 53; Figs. 1-2 suggest that some species may occur in their former ranges. It might be found that others do, too, if the distribution of the Atlantic Slope species was known.

The plate captions of the distributional maps (Pls. 50-53) as modified after Thompson, contain data not repeated elsewhere in this paper. These maps seem to indicate that with the possible exception of *Amnicola dalli johnsoni* and two species of *Hyalopyrgus*, which may have survived or speciated on islands in the Wicomico sea, many have repopulated the peninsula since Wicomico flooding. Some species, found only on the ocean side of the Pamlico terrace, appear to have arrived more recently than those on the inner side of the terrace. While the maps seem to indicate that many species have not yet had time to spread further, it is possible that unsuitable niches, and competition from present incumbents, rather than time is the explanation of this distribution. A number of endemic species, mostly confined to individual springs, many near the edge of the Pamlico shore, suggest rapid speciation.

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TABLE 1.— CORRELATION OF MARINE SHORE LINES

Alt and Brooks (1965) and Alt (1968)		Cooke)1946)		MacNeil (1950)		
Age	Altitude (feet)	Shore Line	Altitude (feet)	Shore Line	Altitude (feet)	Stage
Sangamon	5-10	(Silver Bluff)	5	Silver Bluff	8-10	Post-Wisconsin
Yarmouth interglacial	25-30	Pamlico	25	Pamlico	25-35	Mid-Wisconsin glacial recessionl
Aftonian interglacial	45-50	Talbot	42			
Late Pliocene or Early Pleistocene	70-80	Penholoway	70	Wicomico	100	Sangamon interglacial
Pliocene	90-100	Wicomico	100			
		Sunderland	170	Okefenokee	150	Yarmouth interglacial
Upper Miocene	215-250	Coharie	215			
		Brandywine	270	(not recognized)		Aftonian interglacial

Plate 49

Fig. 1. Okefenokee shore lines during the Yarmouth interglacial stage in the Southeastern States. Much generalized. (After Cooke, 1945, fig. 12; and MacNeil, 1950).

Fig. 2. Wicomico and pre-Wicomico shore lines during the Sangamon interglacial stage in the Southeastern States. (From Cooke, 1945, fig. 13).

Fig. 3. Pamlico and pre-Pamlico shore lines during the mid-Wisconsin glacial recession in the Southeastern States. (From Cooke, 1945, fig. 16).

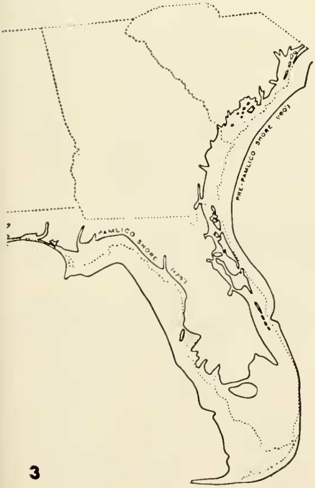
Fig. 4. Shorelines of 19,000 years ago (lowest level of the sea during the Wisconsin glacial stage) and that of 11,000 years ago (when the shore was near the outer edge of the continental shelf except where the land was still isostatically depressed by the ice load). The present shoreline and the future one (if all ice were to melt) are also indicated. The insert diagram shows the changing position of past sea level derived from radiocarbon ages of shallow-water shells and peat deposits. (From Emery, 1967, fig. 9).


BRANDYWINE SHORE
COHARIE SHORE
SUNDERLAND SHORE
OKEFENOKEE SOUND
TRAIL RIDGE
POST-SUNDERLAND SHORE

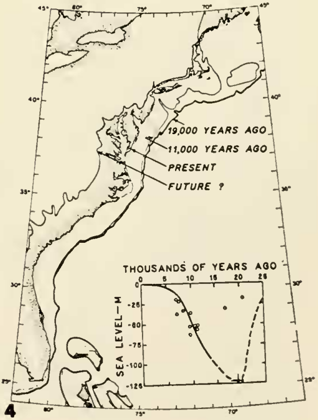
1


WICOMICO SHORE
PRE-WICOMICO SHORE

2


PAMLICO SHORE
PRE-PAMLICO SHORE

3


19,000 YEARS AGO
11,000 YEARS AGO
PRESENT
FUTURE ?
THOUSANDS OF YEARS AGO
0 5 10 15 20 25
SEA LEVEL—M
-25
-50
-75
-100
-125
40°
35°
30°
25°
80°
75°
70°
45°

4

Plate 50

Species of Hydrobiidae, some of which appear to have migrated into peninsular Florida subsequent to Wicomico flooding in the Pliocene. Their general lack of penetration beyond the Pamlico Terrace, formed during the Yarmouth interglacial stage, and the inability of most of them to fully occupy the older part of the peninsula suggest that they may have arrived there much more recently than thought by Thompson (1968: 15) or that suitable niches for their spread are lacking.

Fig. 1. The genus *Amnicola* Gould is widely distributed in North America east of the Rocky Mountains and in Europe. *Amnicola dalli dalli* (Pilsbry and Beecher) and *A. dalli johnsoni* Pilsbry both extend into the Apalachicolan region as far west as Leon County, Florida. Thompson (1968: 159) states that *A. d. dalli* is restricted to springs, spring runs, and spring-fed streams. Since *A. d. dalli* and *A. d. johnsoni* appear to overlap in their distribution in the Suwannee River system and elsewhere, it is doubtful if *johnsoni* is a subspecies as this concept is currently understood, especially since Thompson (1968: 152) says, "[They] intergrade in all conchological and opercular characters."

Fig. 2. The genus *Cincinnatia* Pilsbry is confined to North America and extends from the Great Lakes region south to Florida and west to Texas. *Cincinnatia floridana* (Fraunefeld), represented by black dots, is not known to extend west into the Apalachicolan region beyond the Suwannee River system, where it may have had a *refugium.*

A. *Cincinnatia mica* Thompson. Type locality: A small spring along the west bank of the Ichetucknee River [Suwannee River system] about 1 mile northeast of U. S. Highway 27, Suwannee County, Florida. Known only from the type locality.

B. *Cincinnatia vanhyningi* (Vannata). Type locality: Seminole Springs [head waters of Seminole Creek which flows into Black Creek, into Wekiva River of the St. Johns River system, 3.4 miles northeast of Sorrento] 15 miles east of Eustis, Lake County, Florida. Known only from the type locality.

C. *Cincinnatia petrifons* Thompson. Type locality: Rock Springs [into Wekiva River of the St. Johns River system] about 6.5 miles north of Apopka, Seminole County, Florida. Known oniy from the type locality.

D. *Cincinnatia ponderosa* Thompson. Type locality: Sanlando Springs [into Little Wekiva River of St. Johns River system] 3.1 miles west of Longwood, Seminole County, Florida. Known only from the type locality.

Fig. 3. The genus *Notogillia* Pilsbry is monotypic. *Notogillia wetherbyi* (Dall) is restricted to the Apalachicolan region and the northern part of peninsular Florida west of the St. Johns River system. Pilsbry (1953: 441) described, as a subspecies, *N. wetherbyi perforata* from the Pliocene of St. Petersburg, which, according to Thompson (1968: 101), "is not very different from the present form." That the fossil is found even slightly further south than the living snail tends to support the thesis that the present population is a reintroduction from the Apalachicolan region.

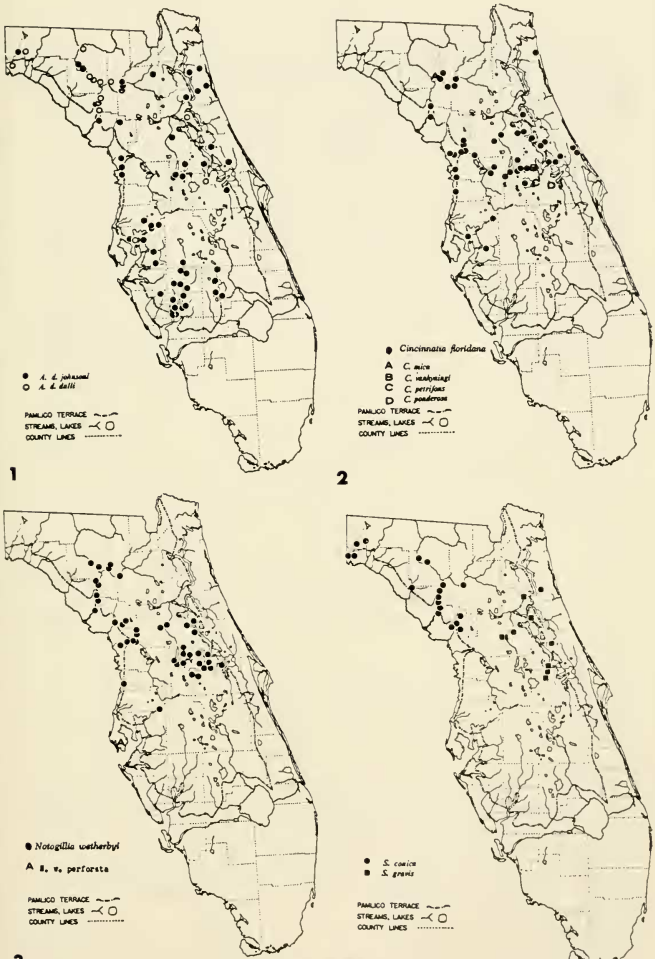


Fig. 4. The genus *Spilochlamys* Thompson is restricted to the Apalachicolan and peninsular Florida regions. *Spilochlamys conica* Thompson is essentially an Apalachicolan species which extends into peninsular Florida in the Waccasassa River system. *Spilochlamys gravis* Thompson is restricted to the St. Johns River system.

The figures are from Thompson (1968) or modified after him.

Plate 51

Species of Hydrobiidae, some of which are restricted to the ocean side of the Pamlico Terrace, formed during the Yarmouth interglacial stage. This distribution suggests that they are from the Atlantic Slope region, or that they have speciated rapidly.

Fig. 1. The genus *Aphaostracon* Thompson is restricted to the Apalachicolan and peninsular Florida regions. *Aphaostracon hypohyalina* Thompson is essentially an Apalachicolan species, since it is almost restricted to the Suwannee River system. *Aphaostracon rhadinus* Thompson. Restricted to northeast Florida above Palatka.

A. *Aphaostracon chalarogyrus* Thompson. Type locality: Magnesia Springs, 3.7 miles west of Hawthorne, Alachua County, Florida. Known only from the type locality.

B. *Aphaostracon xynoclictus* Thompson. Type locality: Fenney Springs, [into Lake Panasoffkee of the Withlacooche River system] 2 miles east of Coleman, Sumter County, Florida. Known only from the type locality.

C. *Aphaostracon pycnus* Thompson. Type locality: Alexander Springs Run, [into St. Johns River system] Lake County, Florida. Known only from the type locality.

Fig. 2. The genus *Amnicola* Gould is widely distributed in North America east of the Rocky Mountains and in Europe. *Amnicola retromargo* Thompson. Suwannee River system of the Apalachicolan region peninsular Florida, restricted to the west side of the St. Johns river system in Clay and Putnam Counties.

Fig. 3. *Amnicola rhombostoma* Thompson. Restricted to the west side of the St. Johns River in Clay and Putnam Counties.

Fig. 4. The genus *Cincinnatia* Pilsbry is confined to North America and extends from the Great Lakes region south to Florida and west to Texas.

Cincinnatia fraterna Thompson, represented by black dots is confined to the lower St. Johns River, mainly to the east side.

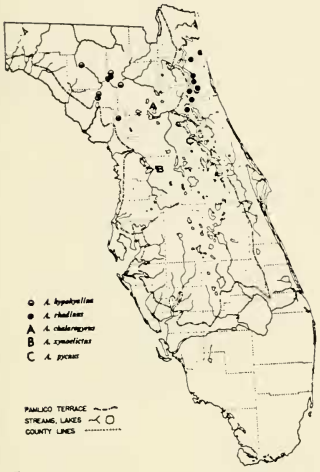
A. *Cincinnatia helicogyra* Thompson. Type locality: Head of the Crystal River, Citrus County, Florida. Known only from the type locality.

B. *Cincinnatia parva* Thompson. Blue Springs [into St. Johns River system] 3 miles west of Orange City, Volusia County, Florida. Known only from the type locality.

C. *Cincinnatia wekiwae* Thompson. Type locality: Wekiwa Springs [into Wekiva River of the St. Johns River system] about 5 miles northeast of Apopka, Seminole County, Florida. Known only from the type locality.

D. *Cincinnatia monroensis* (Dall). Type locality: Brook flowing from Benson's mineral spring, into Lake Monroe, Enterprise, [Volusia County] Florida. Known only from the type locality.

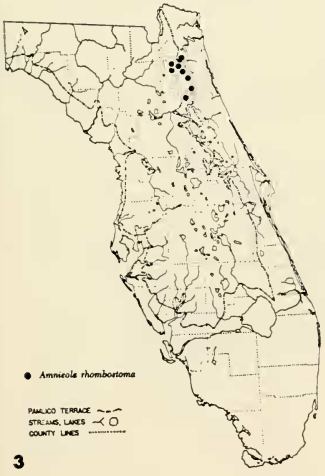
The figures are from Thompson (1968) or modified after him.


A. hypokyllini
A. rhadinus
A. chalcargyrus
A. zymoticus
A. jocosus
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES

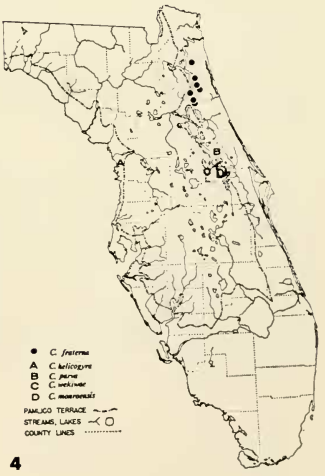
1


Amnicola retromargo
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES

2


Amnicola rhombostoma
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES

3


C. fraterna
C. helicogyra
C. parva
C. wetherbyi
C. monroensis
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES

4

Plate 52

Species of Hydrobiidae all of which are restricted to the ocean side of the Pamlico Terrace formed during the Yarmouth interglacial stage. This distribution suggests that they came from elsewhere recently, or speciated rapidly.

Fig. 1. The genus *Littoridinops* Pilsbry occurs in the coastal areas of the Southern Atlantic Slope region from Central Georgia, through peninsular Florida to the Apalachicolan region. *Littoridinops monroensis* (Frauenfeld) occurs in the Bahama Islands, and lives in brackish and marginal freshwater. It is remarkable for its wide distribution in peninsular Florida on the ocean side of the Pamlico Terrace.

Fig. 2. *Littoridinops tenuipes* (Couper). Southern Atlantic Slope: Altamaha River system and peninsular Florida.

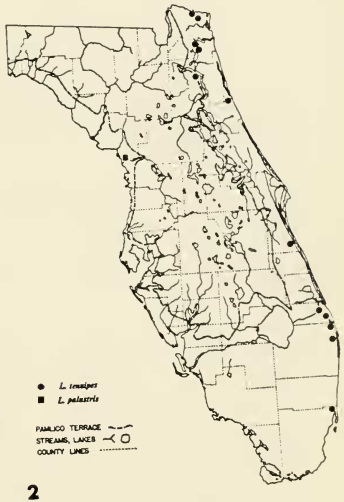
Littoridinops palustris Thompson. Brackish marsh, 3.2 miles SW of Yankeetown, Levy County, Florida. Known only from the type locality.

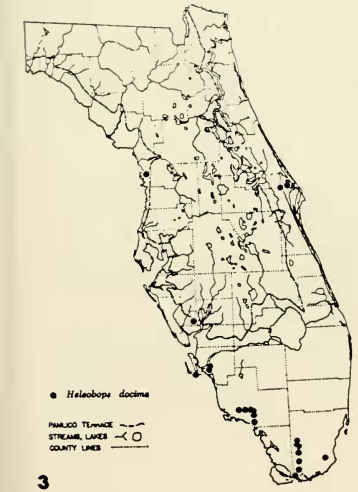
Fig. 3. The genus *Heleobops* occurs in peninsular Florida, Andros Island, and the Bahama Islands. *Heleobops docima* Thompson, confined to brackish water, occurs in peninsular Florida on the ocean side of the Pamlico Terace.

Fig. 4. The genus *Onobops* Thompson occurs from the Southern Atlantic Slope region, in the vicinity of Chesapeake Bay, "and probably has a wider distribution along the Atlantic and Gulf Coasts of North America." (Thompson 1968: 30). *Onobops crassa* Thompson. Known only from the coastal marshes in Dade and Collier Counties, Florida.

Onobops jacksoni (Bartsch). Southern Atlantic Slope, Chesapeake Bay region, Maryland, and Levy County, Florida. The figures are from Thompson (1968) or modified after him.


● Littoridinops monroensis
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES
1


● L. tenuipes
■ L. palustris
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES
2


● Helobiopa dacima
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES
3

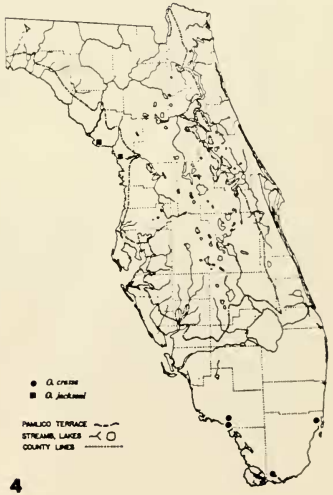

● O. crassa
■ O. jacksoni
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES
4

Plate 53

Species of Hydrobiidae all of which are restricted to the ocean side of the Pamlico Terrace formed during the Yarmouth interglacial stage. (Continued).

Fig. 1. The genus *Pyrgophorus* Ancey is found in the West Indies, exclusive of the Bahama Islands, in southern Florida, and from Texas south to Venezuela.

Pyrgophorus platyrachis Thompson. Restricted to southern Florida on the ocean side of the Pamlico Terrace. A species of this genus, *P. coronatus* (Pfeiffer) occurs in Cuba.

Fig. 2. The genus *Aphaostracon* Thompson is restricted to the Apalachicolan and peninsular Florida regions.

Aphaostracon pachynotus Thompson, represented by black dots, is restricted to the upper half of the St. Johns River near Sanford, south to the everglades.

A. *Aphaostracon asthenes* Thompson. Type locality: Blue Springs [of the St. Johns River system] 3 miles west of Orange City, Volusia County, Florida. Known only from the type locality.

B. *Aphaostracon monas* (Pilsbry). Confined to Wekiwa Springs and a small part of the Wekiva River of the St. Johns River system, Orange County, Florida.

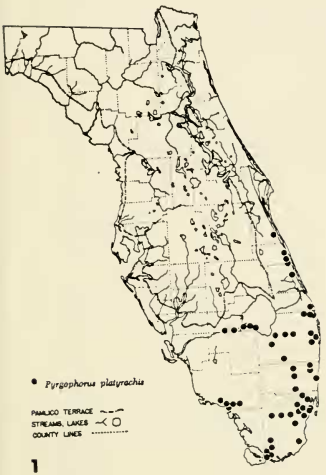
C. *Aphaostracon theiocrenetus* Thompson. Clifton Springs Run [into Lake Jessup of the St. Johns River system] about 2 miles north of Oviedo, Seminole County, Florida. Known only from the type locality.

Two species which may have had *refugia* on islands during Wicomico flooding in the late Pliocene or early Pleistocene.

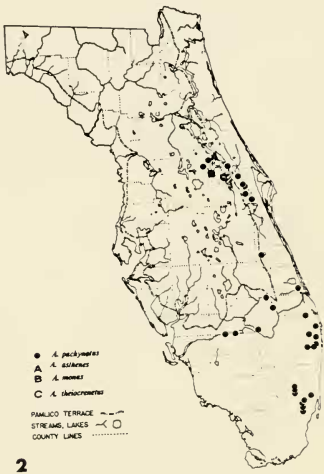
Fig. 3. The genus *Hyalopyrgus* Thompson is restricted to peninsular Florida. *Hyalopyrgus brevissimus* (Pilsbry). Retricted to central Florida on both sides of the Pamlico Terrace.

Fig. 4. *Hyalopyrgus aequicostatus* (Pilsbry). Widely distributed in central Florida.

The figures are from Thompson (1968) or modified after him.


● Pyrgophorus platyrachis
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES

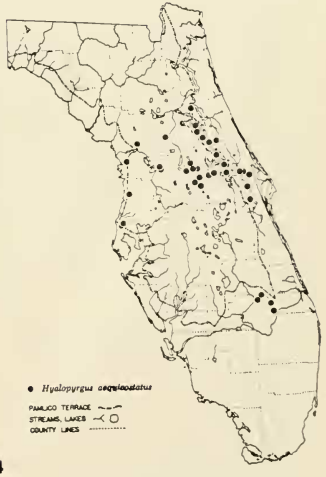
1


● A. packyurites
A A. asthenes
B A. monas
C A. thiocrenetes
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES

2


● Hyalopyrgus brevissimus
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES

3


● Hyalopyrgus aequiradiatus
PAMLICO TERRACE
STREAMS, LAKES
COUNTY LINES

4